SERIES 60 CONTROL
USING 3-ACTION C.A.T. CONTROL UNIT

LEEDS & NORTHRUP

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SERIES 60 CONTROL
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INTRODUCTION

In general, a Series 60 Current-Adjusting Type (C.A.T.) control system comprises an arrangement of the following major components:

(1) A primary element sensitive to the variable quantity to be controlled.

(2) A recorder or indicator which measures the output of the primary element. This instrument, which also contains a control setting device, signals the control unit whenever the measured variable departs from the control point setting.

(3) A control unit which automatically produces an output current proportional—in the range 0 to 5 milliamperes—to the input requirement of the controlled process.

(4) Equipment for translating the current output of the control unit into process input. This is usually a pneumatic diaphragm valve and a Leeds & Northrup Cat. 10970 Electro-pneumatic Converter having a 1 to 5 milliampere input range. However the C.A.T. Control Unit is also adaptable for use with the General Electric "Reactrol" system for control of electrically heated processes. In this application an IR drop produced by the control unit output current serves as the control voltage input to the Reactrol system.

This booklet is intended to apply primarily to the control unit. Information on other components of the system is included only where it pertains to their relationship with the control unit. For more complete information on these other items, the user is referred to other booklets furnished with the equipment.

SPECIFICATIONS

AUTO • MAN SWITCH
Selects automatic or manual operation.

CURRENT ADJUST DIAL
Manually regulates current output.

PROPORTIONAL BAND DIAL
Calibrated 0-500% of recorder scale.

RATE TIME DIAL
0 to 8 minutes graduation. Continuously adjustable.

RESET DIAL
Graduated 0 to 100 repeats per minute. First step above zero is .01 repeat per minute.

APPROACH DIAL
Graduated 0 to 100.

AMBER SIGNAL LIGHT
Amber signal light glows when unit is energized.

RED SIGNAL LIGHT
Red signal light glows when variable exceeds predetermined set point. Setting of recorder safety contact determines light operation.

TERMINAL BOARD
On rear of case. Cutouts take a one inch conduit.

POWER SUPPLY
120 volts, 50 or 60 cycles.

POWER REQUIREMENTS
30 volt-amperes.

AMBIENT TEMPERATURE LIMITS
16 F to 120 F (−9 C to 50 C).

CASE AND DOOR
Metal, for flush mounting.

DIMENSIONS
6-1/2" x 11" x 11".

WEIGHT
About 28 lb.

PART I

DESCRIPTION OF EQUIPMENT

1. EQUIPMENT VARIATIONS

The Series 60 three-action C.A.T. control unit comprises a chassis arranged to plug into an outer case. Both the chassis and the case arrangement may vary, as follows:

(1) The control unit chassis may be Part No. 354162 or Part No. 354181. These parts differ only in that the former is for use with a 120 V, 60 cycle line supply, while the latter requires a 120 V, 50 cycle supply. The chassis are identical in external appearance (Fig. 3).

(2) The control unit may be supplied as part of a Speedomax® H indicating or recording controller, or it may be furnished as a self-contained unit for use with a Speedomax G or Micromax® recorder. In the former instance, the control unit chassis plugs into the lower case of the Speedomax H long door instrument, the door being common to both cases as shown in Fig. 1. The assembly is furnished complete with all necessary wiring between the two cases. Thus the control unit is an integral part of the Speedomax H instrument.

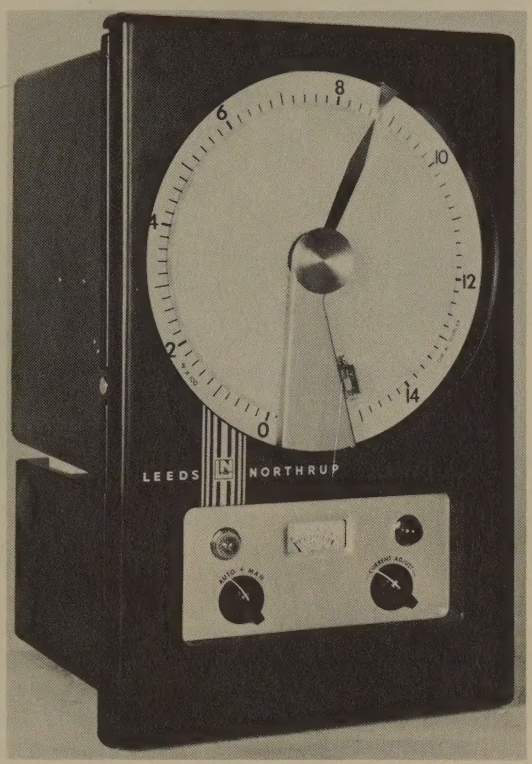


Fig. 1 — Speedomax Type H long door instrument with control unit in lower case.

When supplied for use in conjunction with a Micromax or Speedomax G recorder, the control unit is provided with its own case, as shown in Fig. 2, for mounting separate from the recorder. In this arrangement the unit is identified by a catalog number which varies according to the chassis contained in the case. Thus if the chassis is part #354162, the control unit is Cat. 10877; if the chassis is part #354181, the control unit is Cat. 10877-F.

2. PANEL CONTROLS AND INDICATORS

All switches, dials, and indicating devices used in adjusting and operating the control unit are contained on the chassis front panel. Those commonly employed when the equipment is in service are available at all times through the opening in the control unit door, as shown in Figs. 1 and 2.

Fig. 2 — No. 10877 Control Unit.

Dials used for initial tuning of the control (and only infrequently thereafter), are concealed except when the door is opened, to prevent them from being disturbed during normal operation. Factory and calibration adjustments are mounted internally on the back of the panel. The purpose of each of these devices is given below.

A. AUTO-MAN Switch

With this switch turned to MAN, the control unit can be operated as a remote manual controller. With the switch on AUTO, the control unit functions as an automatic controller. Transfer from manual to automatic operation is accomplished with minimum disturbance of process input, simply by turning the switch from MAN to AUTO -- regardless of whether the controlled variable is at control point or away from it.

The AUTO-MAN switch has a center position which is marked with a dot. Functions of this position are as follows:

(1) On electro-pneumatic control applications, removal of the control unit chassis from its case de-energizes (i.e., closes) a solenoid sealing valve which clamps the pressure on the pneumatic diaphragm valve to hold it stationary. However, when the chassis is unplugged, the controller output current connections might be broken slightly before the sealing valve connections, thereby causing a sudden change in diaphragm valve position.

To avert this possibility, the AUTO-MAN switch should be turned to the dot position before the chassis is unplugged. This de-energizes the sealing valve prior to removal of the chassis.

(2) The dot position of the AUTO-MAN switch allows transfer from automatic to manual control without abrupt change of process input. The procedure for accomplishing this is described in Section 11C.

B. CURRENT ADJUST Dial

This dial has no effect when the AUTO-MAN switch is on AUTO. With the switch on MAN, the CURRENT ADJUST dial regulates the controller output current and is therefore used for remote manual control of process input.

With the AUTO-MAN switch in the dot position the CURRENT ADJUST dial regulates current flow through the dummy load resistance (see Section 2C, below).

C. Output Current Meter

With the AUTO-MAN switch in either the AUTO or MAN position, this panel meter reads the control unit output current. Thus the pointer deflection (in per cent of full scale) gives an approximate indication of process input (in per cent of maximum input).

With the AUTO-MAN switch in the dot position, the system is on automatic control but the output current meter measures manual control current through a dummy load resistance. This dummy load is adjusted to simulate the actual control unit output load. Thus the meter shows the level of process input which will exist when the system is switched to manual operation. This allows preadjustment of the CURRENT ADJUST dial to prevent abrupt change of process input upon switching to MAN (see Section 11C).

D. Signal Lights

The amber signal light glows when the control unit is energized. The red signal light glows when the controlled variable goes above the safety switch setting (see Section 3A) while the process is on automatic control, i.e., while AUTO-MAN switch is in AUTO or dot position.

E. Internal Adjusters

On the back of the panel to the left of the meter are the approach calibrate and meter adjust pots and on the right side are located the dummy-load adjuster and the maximum current adjuster. The approach calibrate (see Section 18H) and meter adjuster (Section 13) are factory adjustments which do not normally require readjustment. The dummy-load adjuster is used to match the dummy-load resistance to the output load resistance of the control unit. The maximum current adjuster

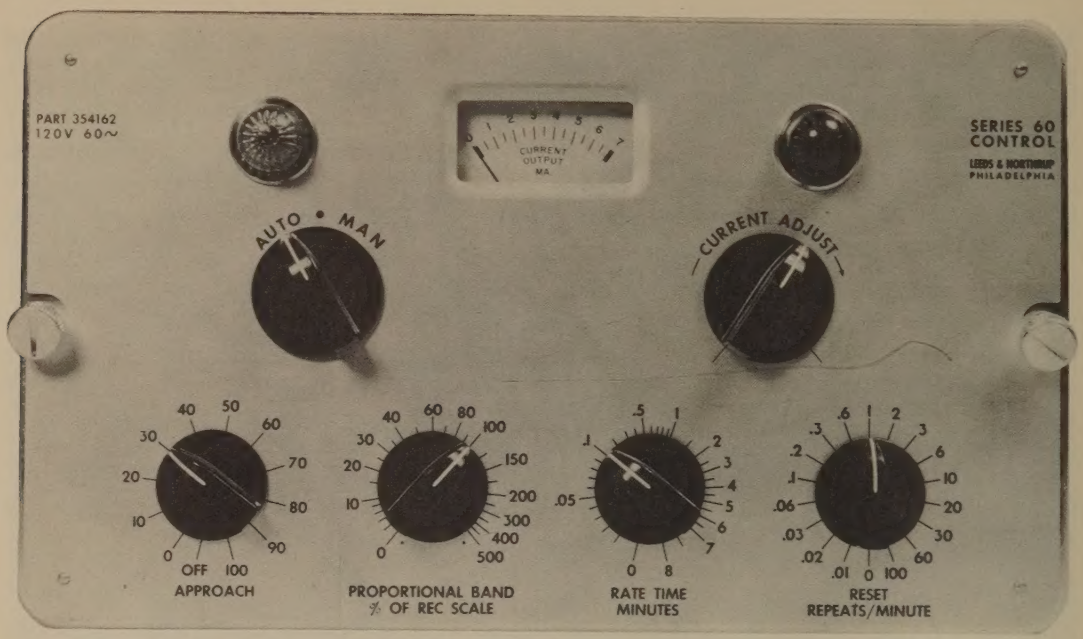


Fig. 3 — Control Unit Chassis.

(Section 10C(3)) is used to select the approximate upper limit of control unit output current. Normally, no adjustment is required if the average line voltage is 115 volts.

F. PROPORTIONAL BAND Dial

Proportional control is a control action in which the change of process input is proportional to the recorder* pen motion. The ratio of pen motion to change of process input is expressed as the proportional band and is adjusted by means of the proportional band dial. A dial setting of 10% for example, means that the recorder pen must travel over 10% of the recorder scale to vary process input from minimum to maximum. Note, however, that for pH applications the proportional band adjustment covers the range of 0-1000% instead of the 0-500% indicated. In these instances the dial markings are one-half the actual value.

G. RESET Dial

Automatic Reset provides floating correction of process input at a speed proportional to the deviation of the recording pen from the control point setting. The ratio of speed to deviation is adjustable by means of the RESET dial. This control action produces a gradual change in process input as long as the recorder pen is off control point. At control point it stops.

*Although the control unit may be used in conjunction with an indicator, a recorder is more often employed. Therefore, for convenience, the term "recorder" is used in this and subsequent sections, and shall be understood to mean "recorder or indicator".

Proportional action alone will not maintain the recorder pen at the control point when process demand changes are encountered. The proportional control provides the rapid and stable response to process demand changes which are required for close control. When reset action is superimposed upon proportional control, it provides the recognition of control point which simple proportional control lacks.

Reset rate is calibrated in "repeats per minute", which term may be explained as follows:

Suppose the recorder pen is at control point. Now suppose that the recorder pen moves away from control point so that the proportional action changes process input by, say, 10% of maximum input. Suppose then that the recorder pen is held steady at this position. The reset action will now produce a further change of process input at a speed which is proportional to the distance the recorder pen is off control point.

If the RESET dial is at 1.0, then in one minute reset action will add another 10% to the process input. That is, the reset action will "repeat" the proportional action once per minute.

H. RATE TIME Dial

Rate action applies a correction to the process input which is proportional to the rate of change of recorder pen position. This corrective action, when used in conjunction with proportional and reset action, aids in overcoming the effects of process capacity and measuring lags which give the process a tendency to overshoot or cycle about the control point. The amount of rate time action depends upon the RATE TIME dial setting.

The RATE TIME dial is calibrated in minutes. The significance of the dial setting is as follows:

Suppose that the recorder pen is moving downscale from the control point at a constant rate. Then, because of proportional action, process input will change—also at a constant rate. Thus, for a given set of conditions, process input might be increasing at the rate of, say, 3% of maximum input per minute due to proportional action only. Now, if the RATE TIME dial were set at 2 minutes, process input would increase by an additional amount equivalent to 2 minutes of proportional action, i.e., 6% of maximum in the example cited.

I. APPROACH Dial

Approach is usually necessary only under conditions of start-up or extended process upset, when saturation of the reset circuit can occur. That is, when process input remains at a limit for an extended period, proportional position and reset actions will not take effect until the controlled variable returns to set point and starts to deviate in the other direction. Overshoot, of course, would be inevitable. The purpose of the approach control function is to provide an electrical shift in proportional band to permit corrective action to begin before set point is reached,

thereby minimizing overshoot. This shift of proportional band is temporary and takes place only if the process input remains at maximum. The effectiveness of the approach feature is a function of the front-panel dial setting, which must be individually tuned to the process under control. The higher the dial setting, the sooner the corrective action takes place.

3. OTHER FEATURES

A. Safety Action

A cam-operated switch, located in the recorder, is arranged so that in the event of excessively high values of the controlled variable, the process input is turned off (on automatic operation only). At the same time, the red signal light on the control unit goes on. The safety action completely bypasses the control unit and, therefore, will protect against any type of control unit failure (but note that for some types of failure, the red signal light does not go on).

4. FEEDBACK UNITS FOR FAST ACTING PROCESSES

The C.A.T. control circuitry requires that a d-c voltage, proportional to process input, be fed back to the control unit. In most applications a suitable feedback signal is developed directly by the control unit output current. However, in some applications involving high speed response to line voltage variations, such as resistance heating or induction heating processes, an auxiliary feedback unit may be employed to develop the feedback signal. The feedback signal is obtained from a transformer connected across the heater winding (resistance heating process) or from a pickup coil (induction heating process). The signal so obtained is rectified, filtered, and adjusted in the auxiliary unit (L&N Part No. 171001 for the transformer coupling and 171002 for the pickup coil coupling). The resultant d-c signal can be used as the feedback signal since, over a sufficiently small range, it varies directly with the process input, regardless of line voltage fluctuations.

In addition to the rectifier and filter components, the feedback units incorporate the following items:

(a) A potentiometer for adjusting the feedback signal to the proper operating level.

(b) In the 171001 feedback unit there are controller output load resistors which may or may not be used in a given installation, depending on the particular needs of the given control device.

(c) A direct transient feedback loop. This is a capacitor loop which bypasses the main feedback loop described above. Its function is to compensate for time lag in the main feedback loop. That is, any change of controller output current is immediately transmitted through the transient feedback loop. Then, as the main feedback signal builds up to its final value, the transient signal decays. The net effect is to provide a feedback

signal having the proper final value, but free of transmission lag which might cause control oscillations.

The auxiliary feedback unit contains several capacitors. Note that it may be necessary to adjust the time constant of the transient feedback loop by changing the number of such capacitors connected in the circuit (see Section 10B(1)(a) or 10B(2)(a)).

PART II

INSTALLATION AND OPERATION

5. UNPACKING

After removing the instrument from its packing case, loosen the chassis fasteners located at each side of the front panel. This is accomplished by turning the knurled fastener heads counterclockwise. The chassis can now be pulled forward out of the case. Remove and discard all packing material and shipping ties from the chassis. Then make sure all plug-in parts are seated firmly in their sockets, before replacing the chassis in the case.

IMPORTANT: If for any reason the control unit is to be sent back to Leeds & Northrup Company, it must be properly packed to prevent damage during shipment. If the original packing material and shipping ties have been removed, all plug-in components should be taken out of their sockets, wrapped separately, and shipped in the same container as the control unit.

6. MOUNTING

(1) If the control unit is supplied as part of a Speedomax H indicating or recording controller, follow the mounting instructions given in the Speedomax H manual.

(2) If the control unit is supplied in a separate case, it should be mounted in a readily accessible location near the recorder (usually directly below the recorder on the panel). The control unit is arranged for flush mounting only. All necessary mounting dimensions are given in Fig. 4.

7. TEMPERATURE LIMITS

The control unit should not be installed in locations where the ambient temperature goes outside the limits 16 F to 122 F (-9 C to 50 C).

8. OTHER EQUIPMENT

For instructions on installing the recorder, control valve, converter, Reactrol equipment, magnetic amplifier, and saturable core reactor, refer to the booklets furnished with such equipment.

On Reactrol installations, mount the 171001 feedback unit in an accessible location near the C.A.T. Control Unit. Locate the 50 V.A. feedback transformer near the furnace to be controlled.

9. WIRING CONNECTIONS

Wiring connections to the various units of the control system are to be made in accordance with the diagram furnished for the system. Special attention should be given to the notes on the diagram concerning direction

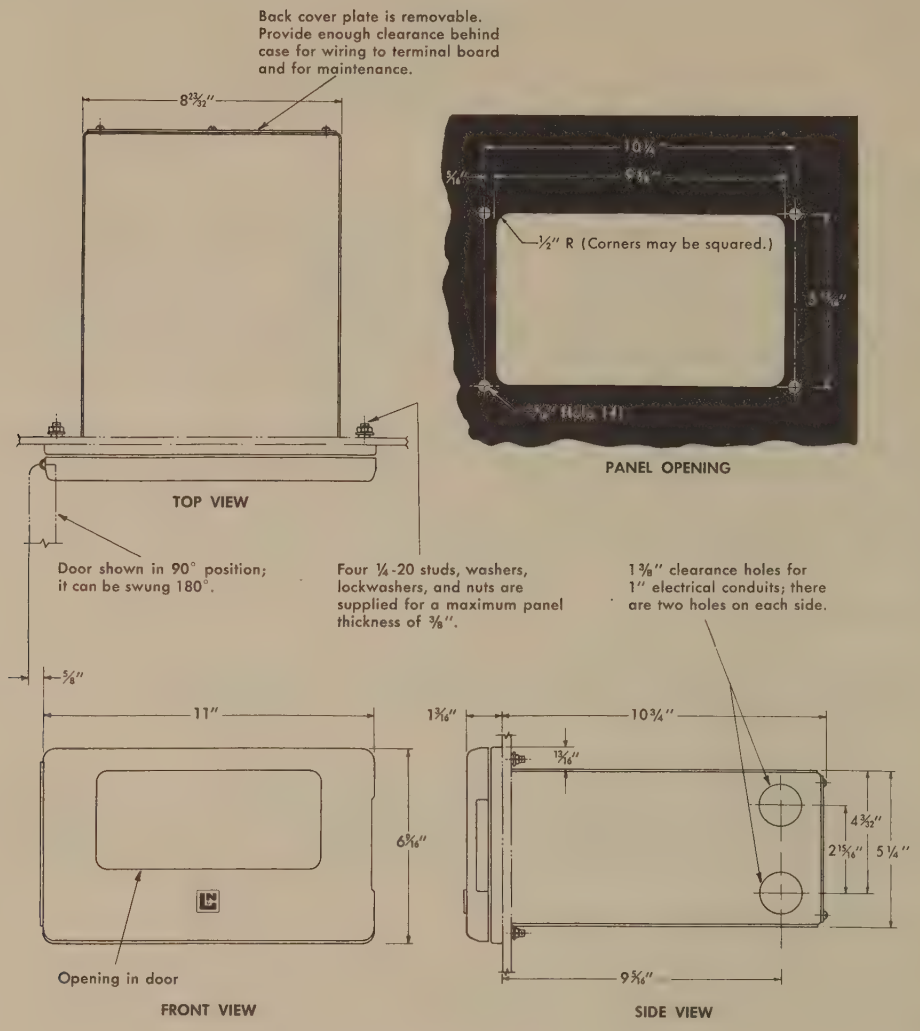

Back cover plate is removable. Provide enough clearance behind case for wiring to terminal board and for maintenance.
8 23/32"
TOP VIEW
10 1/4"
1/2" R (Corners may be squared.)
PANEL OPENING
Door shown in 90° position; it can be swung 180°.
Four 1/4-20 studs, washers, lockwashers, and nuts are supplied for a maximum panel thickness of 3/8".
1 3/8" clearance holes for 1" electrical conduits; there are two holes on each side.
5/16"
11"
6 3/16"
Opening in door
FRONT VIEW
1 3/16"
10 3/4"
13/16"
4 3/32"
2 15/16"
5 1/4"
9 5/16"
SIDE VIEW

Fig. 4 — Outline and mounting dimensions for control unit.

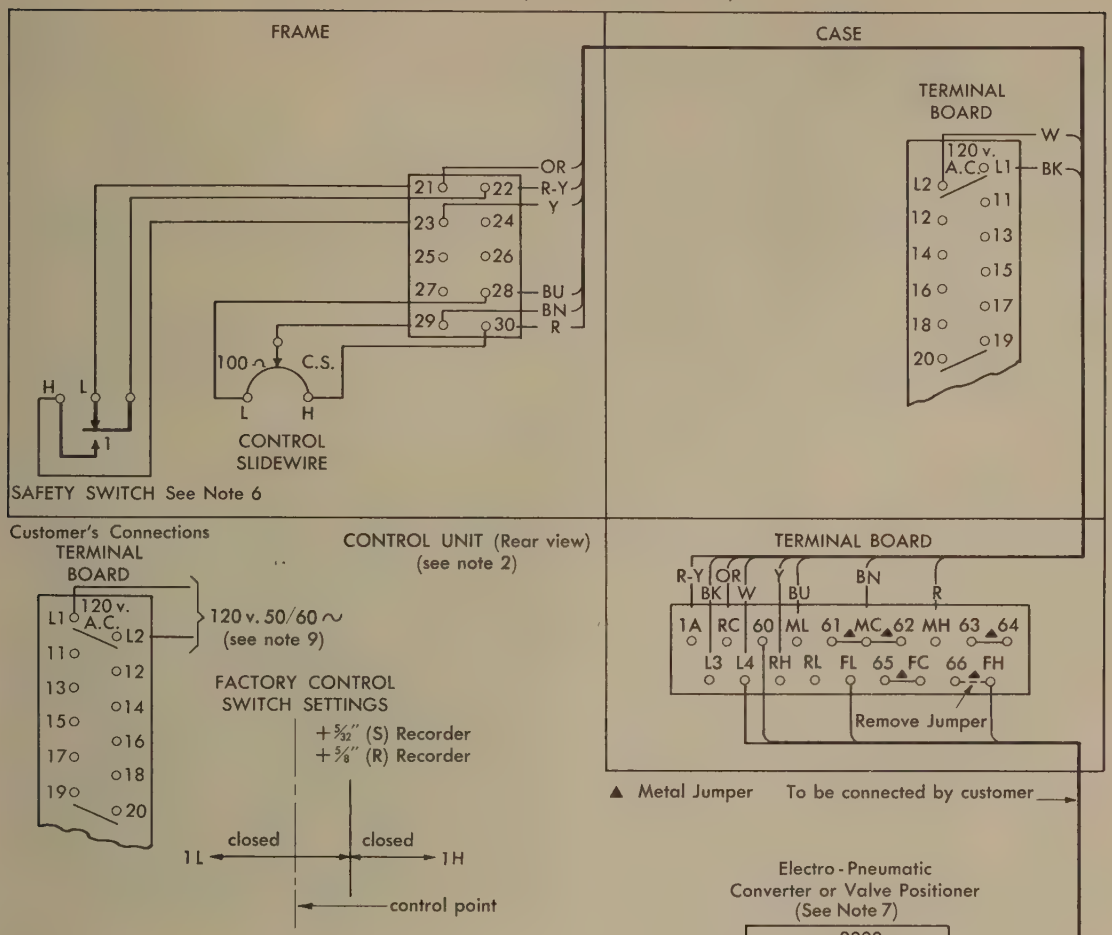
of valve travel and reversal of control action.

Figs. 5 and 6 show wiring diagrams of electro-pneumatic control systems using Speedomax H and Speedomax G measuring instruments respectively. Since these circuits (which use L&N No. 10970 Electro-pneumatic converters) represent the most frequently used Series 60 C.A.T. Control arrangements, the diagrams are reproduced here for convenient reference. Schematic and actual internal wiring of the control unit is shown in Figs. 14 and 15.

For Reactrol installations, modify the Reactrol panel internal wiring in accordance with the notes on the L&N installation diagram. This

SPEEDOMAX H and CONTROL UNIT ASSEMBLY

SPEEDOMAX H (Front View, See Note 1)



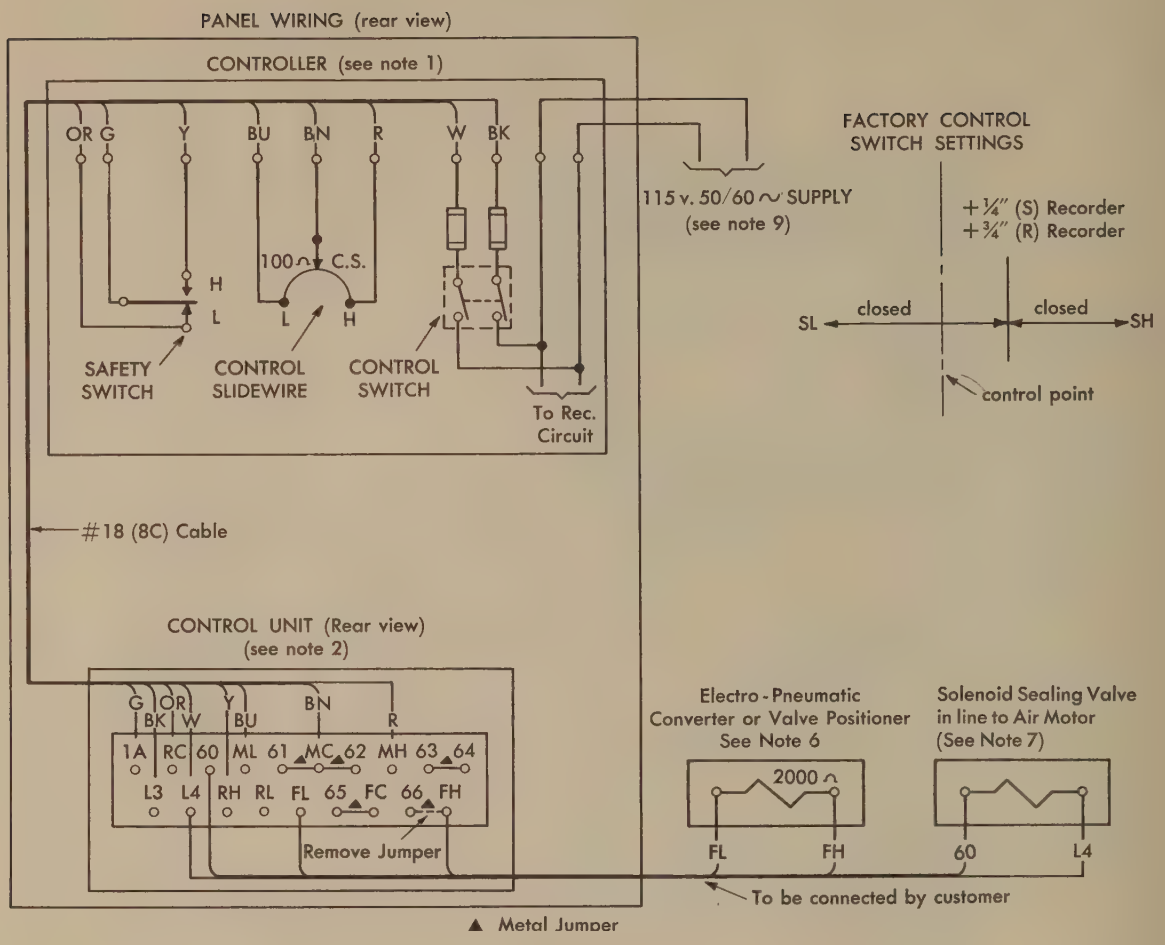
NOTES

1. For Speedomax "H" measuring circuit connections see separate diagram.
2. For control unit internal wiring see diagram at back of book.
3. Wired as shown when Speedomax "H" indicator pointer moves to left side of Control Point, output current increases and position meter goes towards 100. Safety action operates to cut off current.
4. Factory safety switch setting is as indicated. It may be set closer to but not beyond the high end of the control slidewire.
5. To reverse control action interchange leads ML with MH and RC with RH. Set safety switch to operate near low end of control slidewire. See directions for reversing manual setter markings.
6. Switches are rated for 1 Amp. at 120v A. C. non-inductive.
7. For lower resistance converter or positioner add suitable resistor in series with lead to FL to make total resistance 2000 Ω (approx.).
8. Sealing Valve, if used, holds control valve in fixed position following current interruption to converter or positioner coil. If not used omit external connections to terminals L4 and 60.
9. Measuring circuit requires grounding of L2 side of line. If power supply cannot be grounded, add isolating transformer and ground L2 terminal.

COLOR CODE

BK — Black	OR — Orange
W — White	Y — Yellow
G — Green	GY — Gray
R — Red	PU — Purple
BU — Blue	PK — Pink
BN — Brown	LBU — Light Blue

Fig. 5 — Wiring connections (B-C-05-18-10) for series 60 3-Action C. A. T. control using electro-pneumatic converter and Speedomax Type H measuring instrument.



NOTES

1. For controller terminal markings and measuring circuit connections see separate diagram furnished with instrument.
2. For control unit internal wiring see diagram at back of book.
3. Wired as shown, when Controller indicator pointer moves to left side of Control Point, output current increases and position meter goes towards 100. Safety action operates to cut off current.
4. To reverse control action interchange leads ML with MH and RC with RH. Set safety switch to operate near low end of control slidewire. See directions for reversing manual setter markings.
5. Factory safety switch setting is as indicated. It may be set closer to but not beyond the high end of the control slidewire.
6. For lower resistance converter or positioner add suitable resistor in series with lead to FL to make total resistance 2000Ω (approx.).
7. Sealing Valve, if used, holds control valve in fixed position following current interruption to converter or positioner coil. If not used omit external connections to terminals L4 and 60.
8. See directions for reversing meter markings.
9. MG side of line must be grounded. If power supply cannot be grounded, add isolating transformer and ground MG terminal.

COLOR CODE

BK — Black	OR — Orange
W — White	Y — Yellow
G — Green	GY — Gray
R — Red	PU — Purple
BU — Blue	PK — Pink
BN — Brown	LBU — Light Blue

Fig. 6 — Wiring connections (B-MSS-77-AA-10) for Series 60 3-Action C. A. T. control using electro-pneumatic converter and Speedomax Type G measuring instrument.

modification converts the Reactrol panel coarse and fine position adjustments to coarse and fine bias adjustments.

The 50 V.A. feedback transformer employed in Reactrol applications must deliver approximately 115 volts a-c to the feedback unit when maximum power is applied to the furnace. On three-phase installations, the primary of the feedback transformer can be connected across any phase, or from any input connection to neutral on the furnace.

IMPORTANT: When making wiring connections check the jumper between terminals FC and 65 of the control unit terminal board. This jumper must be present unless otherwise specified on the installation diagram.

10. PRELIMINARY CHECKS AND ADJUSTMENTS

After the installation is completed the operation of each unit of the control system should be checked before the equipment is actually put into service. General checking procedures for recorder, electro-pneumatic converter, Reactrol equipment, etc., are to be performed according to the separate instructions furnished with such equipment. Preliminary checks and adjustments specific to operation of the C.A.T. system are given in this section.

NOTE: In electro-pneumatic installations it should be possible to perform the checks described below without disturbing the process. Thus the block valves on each side of the diaphragm control valve must be closed during the checks.

A. Recorder Or Indicator

Check the recorder to be sure that it is indicating and recording the output of the primary element properly. If desired, the control can be turned off during this check by placing the CONTROL ON-OFF switch in the OFF position, if such a switch is provided. In the instance of a Speedomax H instrument having no CONTROL ON-OFF switch, the control may be turned off by removing the control unit chassis from its case.

Check the setting of the safety switch, or the circuit maintaining switch, which is located in the recorder. The factory setting of the switch is indicated on the control installation diagram. Usually the safety switch is set to operate when the measuring pointer is above the set-point indicator by 2 1/2% of full scale, but it may be adjusted to operate for a departure as great as 10%. On pH, conductivity, gas analysis, and other processes which cannot stand the abrupt changes produced by safety action, no safety switch is used, but a circuit maintaining switch is provided. This circuit maintaining switch is set to operate when the control slidewire contact is at the high end of the control slidewire.

The control slidewire, located in the recorder, normally requires no initial adjustment. However, if the factory setting has been disturbed, a rough preliminary adjustment should be made as follows:

Line up the recorder scale pointers and pull the control unit chassis out of its case. Using a suitable ohmmeter, adjust the control slidewire until the resistance measured between the ML and MC terminals of the control unit case is equal to that between the MC and MH terminals.

In all cases, a precise adjustment of the control slidewire should be made after the unit is placed on automatic control, as instructed in Section 10C(4).

B. Feedback Unit Adjustments

(1) Adjustment Of Systems In Which 171001 Feedback Unit Is Used

Notes: The use of a transformer is required with this unit for two reasons, (1) isolation, (2) voltage matching.

The 171001 unit also may be employed with processes in which an M-G Set is controlled as the power source. Such M-G Sets can operate at frequencies up to 10,000 cps.

(a) Transient Feedback Capacitance

Determine the proper value of feedback capacitance to be connected in the direct transient feedback loop (i.e., between terminals 1 and 5 of the 171001 feedback unit). This value is found by means of the following formula:

$$\text{Transient Feedback Capacitance (in microfarads)} = \frac{\text{Control loop time constant (in seconds)} \times 1000}{2}$$

The control loop time constant is the interval of time required for the process to reach two-thirds of its final value when a sudden change is made in the control unit output. Normally the time constant is largely determined by the saturable core reactors in the system, so that a good approximation will be had if the time constant for the saturable reactor is used. When two or more reactors have their control windings connected in series, the sum of their individual time constants should be used. Located in the feedback unit are four 500 microfarad capacitors which should be connected as follows:

Control Loop Time Constant	Capacitor Connection Between Terminals 1 and 5 of Feedback Unit
1/2 second	2 in series
1 "	1
2 "	2 in parallel
3 "	3 in parallel
4 "	4 in parallel

Polarity of the capacitors must be as shown on the elementary wiring diagram. Where the time constant is greater than four seconds, it will be necessary to connect additional capacitors across terminals 1 and 5 of the feedback unit.

Note that the feedback unit is supplied with two of the four capacitors connected in parallel. If it is not possible to determine the control loop time constant before energizing the system, it is suggested that this value of capacitance be used until found to be incorrect (see Section 10B(1)(d) below).

(b) Feedback Voltage Check

Energize all equipment, including the furnace supply. Connect an a-c voltmeter between terminals 6 and 7 of the feedback unit. Then manually increase the furnace input (heater current) to its maximum value by means of the C.A.T. manual control. If the feedback transformer is suitable for this application (see Section 9) the a-c meter reading will rise to between 90 and 130 V.

(c) Feedback Voltage Adjustment

Connect a d-c voltmeter between terminals FL(+) and FC of the C.A.T. control unit. Again increase the furnace input to maximum, using the C.A.T. manual control. Then set the adjuster in the feedback unit to obtain a reading of 10 V on the d-c voltmeter. (NOTE: If it is not feasible to drive the furnace heaters at maximum power, this adjustment can be made so that 50% of maximum furnace power produces a 5 V reading on the d-c voltmeter.)

(d) Feedback Capacitance Check

Turn off the recorder and line up the recorder scale pointers. Set the RESET and RATE TIME dials to zero, and PROPORTIONAL BAND to 100. Turn the AUTO-MAN switch to AUTO and observe the control unit output current. If oscillations commence, transient feedback capacitance must be increased (see 10B(1)(a) above). When stable conditions are obtained, change the recorder set-point indicator by about 10% of full scale (in the direction which does not operate the safety switch) and observe a like change in control unit output current. The transition should be smooth but not sluggish. If the current requires more than about 1/2 second to reach its new value, the transient feedback capacitance must be decreased. Do not proceed further until the proper capacitance has been obtained.

(2) Adjustments Of Systems In Which 171002 Feedback Unit Is Used

(a) Transient Feedback Capacitance

Determine the proper value of feedback capacitance to be

connected in the direct transient feedback loop (i.e., between terminals 3 and C1 of the 171002 feedback unit). This value is found by means of the following formula:

$$\text{Transient Feedback Capacitance (in microfarads)} = \frac{\text{Control loop time constant (in seconds)} \times 1000}{2}$$

The control loop time constant is the interval of time required for the furnace to reach two-thirds of its final value when a sudden change is made in the control unit output. Normally the time constant is largely determined by the induction generator in the system, so that a good approximation will be had if the time constant for the induction generator is used. Located in the feedback unit are three 50 microfarad capacitors which should be connected as follows:

Control Loop Time Constant	Capacitor Connection Between Terminals 3 and C1 of Feedback Unit
0.1 second	1
0.2 "	2 in parallel
0.3 "	3 in parallel

Polarity of the capacitors must be as shown on the elementary wiring diagram. Where the time constant is greater than 0.3 second, it will be necessary to connect additional capacitors across terminals 3 and C1 of the feedback unit.

If it is not possible to determine the control loop time constant before energizing the system, it is suggested that one 50 microfarad capacitor be used until found to be incorrect (see Section 10B(2)(c) below).

(b) Feedback Voltage Adjustment

The 171002 feedback unit has been designed for use with 300 kc systems. It probably can be used with systems operating from 100 kc to 600 kc, depending on the pickup coil design. (Pickup coils are not furnished by L&N.)

The pickup coil design and configuration should be such that, after all equipment has been connected as shown on the installation diagrams, and all equipment has been energized, a d-c voltmeter connected between terminals FL(+) and FC(-) can be made to read 10 volts by moving the adjuster in the feedback unit. (If pickup coil leads are shielded, this shield should be connected to terminal FC of the control unit.) This adjustment should be made when the induction generator is operating at maximum level. (If it is not feasible to operate the induction generator at maximum level, the adjustment can be made so that 50% power produces a reading of 5 volts on the voltmeter.)

Two types of pickup coils may be utilized, as indicated below.

(1) Pickup Coil Made By Placing A Loop Around The Lead To The Inductor

In this design, the pickup coil should be made as a single loop, so constructed and arranged that no motion is permitted between the loop and the lead around which it is placed.

The C.A.T. unit should be operated in the MANUAL position and the signal to the induction generator gradually increased from 0 to 5 ma. As the C.A.T. unit output is increased, the adjuster in the feedback unit should be manipulated so that the d-c voltmeter (connected between FL and FC) does not exceed 10 volts. CAUTION: Do not permit the voltmeter reading to exceed 12 volts or the rectifiers in the feedback unit may be damaged. If 10 volts cannot be obtained when the C.A.T. unit output is 5 ma, it will be necessary to rebuild the pickup coil to include 2 loops instead of one, and possibly change the distance between the loops and the lead to the inductor.

(2) Pickup Coil Made By Placing A Coil Of Wire Near One Lead Or Between The Leads To The Inductor

This method is recommended by L&N since the pickup coil can be rigidly mounted, will be out of the way and less subject to damage, and presents less of a problem in the event of need for adjustment.

The coil should be made by winding approximately 20 turns of insulated wire (18 to 22 gage) on a non-conducting cylinder (approximately 1/2" in diameter) such as wood or plastic. Mount the coil between the leads to the inductor with the axis of the coil perpendicular to the plane through the leads. If the leads to the inductor cannot be spread far enough to mount the pickup coil between them, mount it adjacent to one of these leads. However, in the latter method of mounting, the coupling will be less efficient and more turns will be required on the pickup coil.

The C.A.T. unit should be operated in the MANUAL position and the signal to the induction generator gradually increased from 0 to 5 ma. As the C.A.T. unit output is increased, the adjuster in the feedback unit should be manipulated so that the d-c voltmeter (connected between FL and FC) does not exceed 10 volts. CAUTION: Do not permit the voltmeter reading to exceed 12 volts or the rectifiers in the feedback unit may be damaged. If 10 volts cannot be obtained when the C.A.T. unit output is 5 ma, it will be necessary to add more turns to the pickup coil.

(c) Feedback Capacitance Check

Turn off the recorder and line up the red and black pointers. Set the RESET and RATE TIME dials to zero, and PROPORTIONAL BAND to 100. Turn the AUTO-MAN switch to AUTO and observe the control unit output current. If oscillations commence, transient feedback capacitance

must be increased (see Section 10B(2)(a) above). When stable conditions are obtained, change the recorder set-point indicator by about 10% of full scale (in the direction which does not operate the safety switch) and observe a like change in control unit output current. The transition should be smooth but not sluggish. If the current requires more than about 0.05 second to reach its new value, the transient feedback capacitance must be decreased. Do not proceed further until the proper capacitance has been obtained.

C. Control Checks And Adjustments

(1) Manual Operation

With the AUTO-MAN switch on MAN, snap the CONTROL ON-OFF switch to ON, or plug the control unit chassis back into its case, if it has been removed during preceding checks. (On Reactrol installations, place the Reactrol panel on automatic control.) Then turn the CURRENT ADJUST dial and observe that the setting of this dial determines the reading of the current output meter on the control unit panel.

Set the CURRENT ADJUST dial to obtain a reading of 4 ma on the panel meter. Then turn the AUTO-MAN switch to its center (dot) position and adjust the dummy load (adjuster located on rear of panel to the right of the meter) until meter again reads 4. Meter will now read the same on both "dot" and MAN positions for any setting of the CURRENT ADJUST dial.

(2) Automatic Operation

With the AUTO-MAN switch on MAN, turn the CURRENT ADJUST dial to bring the meter reading to 3. Then proceed as follows:

(a) Set control unit dials thus:

PROPORTIONAL BAND	50
RESET	0
RATE TIME	0
APPROACH	OFF

(b) Set the scale pointers together.

(c) Turn the AUTO-MAN switch to AUTO.

(d) Run the measuring pointer downscale from set point and observe the direction in which the process input will change. If the direction is wrong to control the process (e.g., for electro-pneumatic control of a heating process the fuel valve should open on low temperature), change the wiring as indicated on the diagram to reverse the control action.

(e) Move the measuring pointer in the proper direction to operate the

safety switch. Process input should now operate to the safe limit (e.g., on a heating process, excessively high temperature should shut fuel off). This procedure checks the safety action.

(3) Maximum Current Adjustment

This adjustment (behind the front panel on the right side of the meter) has been set at the factory and no readjustment is necessary on installations where the normal (average) line voltage is 115 V a-c. If average line voltage is higher or lower than 115 V, or if the adjustment is disturbed, readjustment should be made as follows:

(a) With line voltage at its average value, turn the AUTO-MAN switch to AUTO and set the RESET dial to 100. Leave the proportional band setting at 50.

(b) Turn the control setter to produce maximum deflection of the panel meter. This maximum reading is obtained with the control slidewire contact at either the high or low end of its slidewire.

(c) Turn the maximum current adjuster (behind the panel) to obtain a reading of 5.25 (estimated) on the panel meter.

(4) Final Adjustment Of Control Slidewire

The following adjustment should be made before placing the process on control. Subsequently, it should be repeated whenever a new control unit chassis is substituted for the one in use.

(a) Set the control unit dials thus:

PROPORTIONAL BAND	20
RESET	10
RATE TIME	0
APPROACH	OFF

(b) With the AUTO-MAN switch on MAN, set the CURRENT ADJUST dial to bring the panel meter to approximately mid-scale.

(c) With the scale pointers together, switch to AUTO.

(d) Keeping the scale pointers together, adjust the position of the control slidewire to stop any drift of the meter reading.

(e) Gradually increase the setting of the RESET dial, making small control slidewire readjustments to hold the meter reading steady. The final adjustment should be made with the RESET dial at 100. Note that if the meter goes off scale at any time, it can be brought on scale by temporarily switching to MAN, turning the CURRENT ADJUST dial, and transferring back to AUTO.

11. PLACE PROCESS ON CONTROL

A. Preliminary Adjustments (For Electro-pneumatic Systems Only)

(1) Start the recorder and set the control point.

(2) Set the control dials at the following initial settings:

PROPORTIONAL BAND	50
RESET	.03
RATE TIME	0
APPROACH	OFF

(3) Set the AUTO-MAN switch to MAN and turn the CURRENT ADJUST dial to close the control valve.

(4) Open the block valves on both sides of the control valve.

(5) Close the by-pass valve which is across the control valve a small amount and then turn the CURRENT ADJUST dial to open the control valve just enough to keep the recorder pen at the desired control point. Continue this procedure of closing the by-pass valve a small amount and opening the control valve a small amount to hold the process steady until the by-pass is entirely closed.

The process can now be controlled by remote manual operation of the control valve by means of the CURRENT ADJUST dial. It should be operated this way for a time and the nature of the record carefully noted. If cycling occurs during manual operation, the cause should be investigated and eliminated if possible, before the transfer to automatic control is made.

B. Transfer From MAN To AUTO

To transfer the system from manual to automatic control, simply turn the AUTO-MAN switch to AUTO without pausing in the "dot" position. Transfer is accomplished without abrupt change of process input, regardless of whether the controlled quantity is at the control point or away from it.

C. Transfer From AUTO To MAN

The system can be transferred from automatic to manual operation simply by turning the AUTO-MAN switch directly to MAN. However, this causes process input to change suddenly to the new value corresponding to the manual control setting. If such an abrupt change of input would upset the process, it can be avoided as follows:

With the system on automatic control, note the reading of the panel meter. Then turn the AUTO-MAN switch to the "dot" (center) position and adjust the CURRENT ADJUST dial to obtain the same meter reading as just noted. The AUTO-MAN switch can now be moved to MAN without producing any change of process input.

D. Removal Of Control Unit Chassis

On electro-pneumatic installations, turn the AUTO-MAN switch to its center (dot) position before pulling the control unit chassis from its case. The diaphragm control valve will remain stationary in its last position (see Section 2A).

On Reactrol installations, removal of the chassis will cause furnace input power to drop to minimum.

12. ADJUSTING CONTROL UNIT TO A PROCESS

While there are several methods of predicting approximate control settings by observing process performance, such methods are often difficult and do not always yield best results. A more practical means of securing good control adjustments is to use a systematic experimental approach. One recommended approach is outlined in this section.

In adjusting any controller, and particularly a temperature controller, there is no substitute for patience. Adjustments made too close together, without allowing time for conditions to stabilize, very frequently lead to incorrect conclusions and an over-all loss of time in producing a final adjustment. On some processes where the operating conditions vary widely, it may be necessary to make adjustments which are a compromise in order to meet this wide range of conditions. In practically all cases, it is good practice to avoid tuning a controller so that it is on the verge of a cycling condition, because minor changes in conditions on the job, such as a slight change in pressure in the fuel system or a deposit on the thermocouple which increases the measuring lag, will throw the control into a cycle. Good controller adjustments are those which produce satisfactory results and still retain stability.

Systems with program control (such as cam type or motor driven set point) may encounter different control characteristics as the control temperature setting is varied through the program cycle. Therefore, it may be necessary to concentrate on the most critical part of the control cycle when making the controller adjustments.

To compensate for the calibration offset of the proportional band adjustment when using a 40% or a 100% control slidewire instead of the normal 20% control slidewire, refer to Section 18G.

After the best control settings have been determined they should be recorded, in order to facilitate resetting in case adjustments are disturbed. A label is provided inside the door, facing the control unit panel, with spaces for noting the settings.

A. Adjust Proportional Band

With RATE dial set to zero, RESET dial set to .03 and AUTO-MAN switch on AUTO, adjust the proportional band. The usual procedure is to start with a reasonably wide proportional band (about 50 for temperature

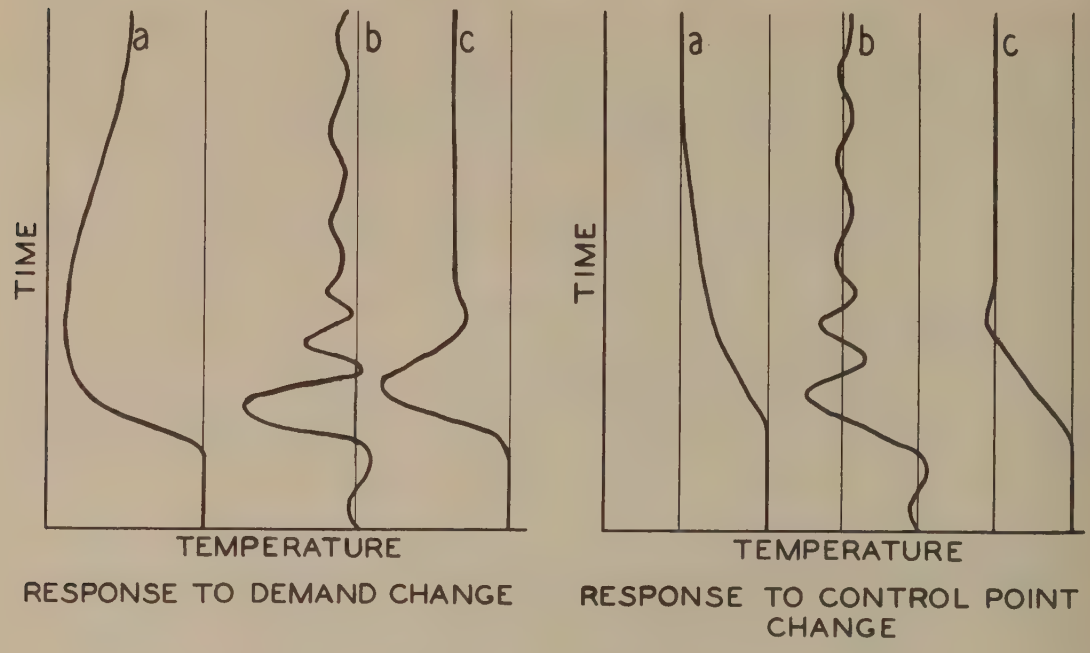


Fig. 7 — Effects of Proportional Band adjustment:
Curves (a), Proportional Band too wide;
Curves (b), Proportional Band too narrow;
Curves (c), Proportional Band correct.

applications) and then decrease the setting until a cyclic control record results. It is recommended that small control point changes be made after each adjustment in order to throw a small upset on the system to reveal any tendency to cycle. Once a cycle is obtained, note the approximate frequency of the cyclic response, and then widen the proportional band until the cycle disappears.

The effects of various proportional band settings are shown in Fig. 7.

NOTE ON PROPORTIONAL BAND ADJUSTMENTS

When making controller adjustments, it should be observed that a change in PROPORTIONAL BAND setting produces a corresponding change of process input. If the reset rate is sufficiently high this change is temporary and causes no change (or only a small pip) in the control record. However, when reset rate is low the input change will persist, thereby producing a persistent shift in the control record. With zero reset action, this shift will be permanent.

Consequently, when making adjustments as instructed above (and also in 12B), the operator should expect a shift in the control record after each change of the PROPORTIONAL BAND setting. Such shifts can be avoided by first transferring to MAN (by "bumpless" transfer procedure

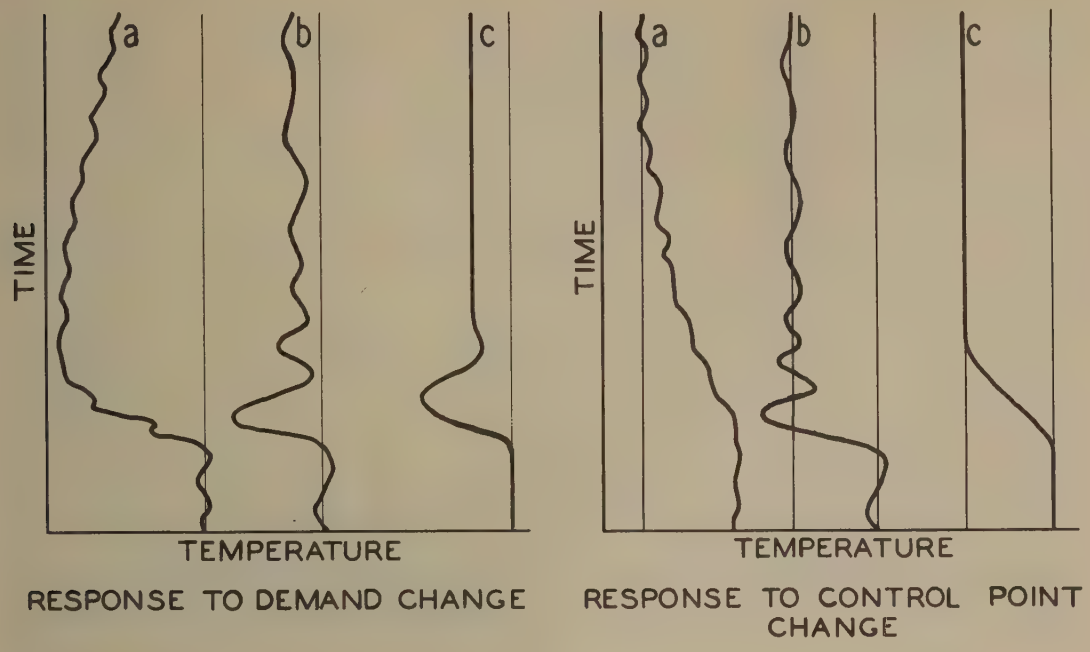


Fig. 8 — Adjustment of Proportional Band and Rate Time:
Curves (a), Proportional Band too wide, Rate Time too long;
Curves (b), Proportional Band too narrow;
Curves (c), both correct.

described in 11C) and then making the desired proportional band adjustment, before turning back to AUTO. If this procedure is not followed, the operator must distinguish between shifts caused by proportional band adjustments and cycling produced by a too-narrow proportional band setting. Confusion of these conditions will be avoided if sufficient time is allowed for the system to stabilize after each adjustment.

B. Introduce Rate Action

Now introduce the minimum amount of rate action by turning the rate knob to .01. To determine the effect of this rate action, throw minor upsets into the system by making small changes in the control point. If an oscillation, which is somewhat faster in frequency than the oscillation caused by a too-narrow proportional band, develops in the system the process is obviously one which will not take rate action. In this case, turn the rate dial back to zero and proceed with the reset adjustment as instructed in C below.

It is advisable, particularly on complicated processes, to watch the effects of control adjustment on other controllers on the process. When small changes in control point are made in a system utilizing rate action, large changes of process input result. It is possible (but not common) for this to upset other controllers on the same process so badly as to indicate that rate action should not be used. In this instance also, the RATE dial should be turned back to zero.

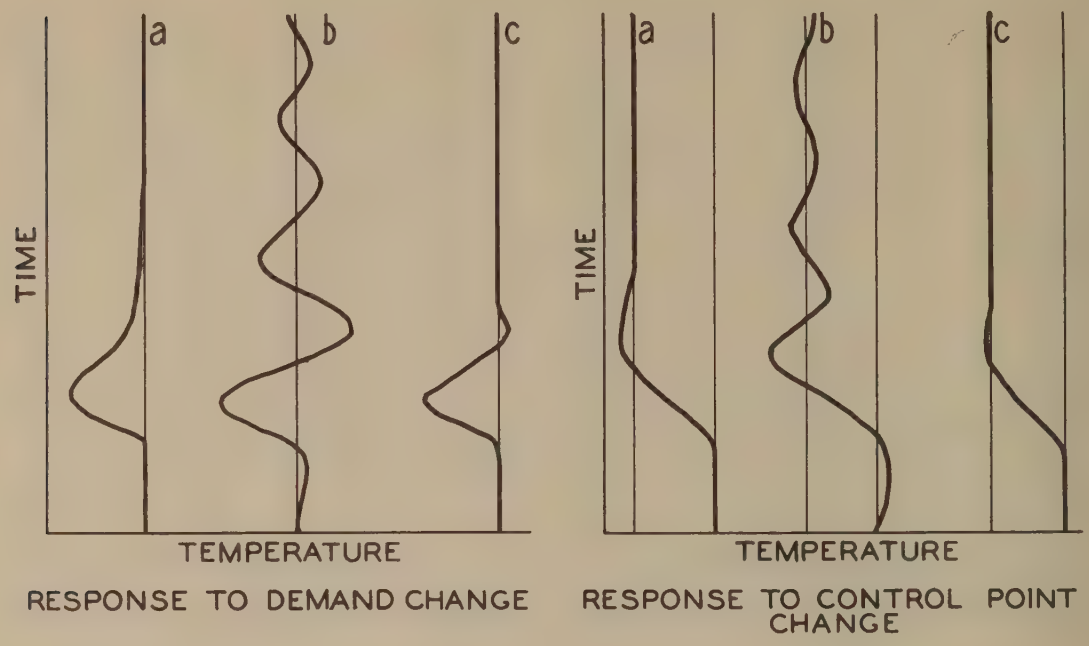


Fig. 9 — Effect of Reset Adjustment in proportional - plus - reset control:
Curves (a), reset too slow;
Curves (b), reset too fast;
Curves (c), reset correct.

Assuming that neither of the above conditions exist, the rate time should be progressively increased. Minor upsets should be introduced into the system to check the effect of such increase.

Normally, as rate action is introduced, a further reduction may be made in the proportional band width. Thus the adjustment becomes an increase in rate time and a decrease in proportional band width.

While making the foregoing adjustments, carefully observe the control record. It is important to note the frequency of any oscillations which may occur. An oscillation of about the same frequency as those obtained during the proportional band adjustment indicates that the proportional band is too narrow and should be increased. An oscillation which is appreciably faster indicates that rate time is too long and should be decreased.

Fig. 8 illustrates the results which might be expected in this stage of adjustment.

C. Add Automatic Reset

After the adjustments of the proportional band and rate time have been made, automatic reset should be introduced into the control action.

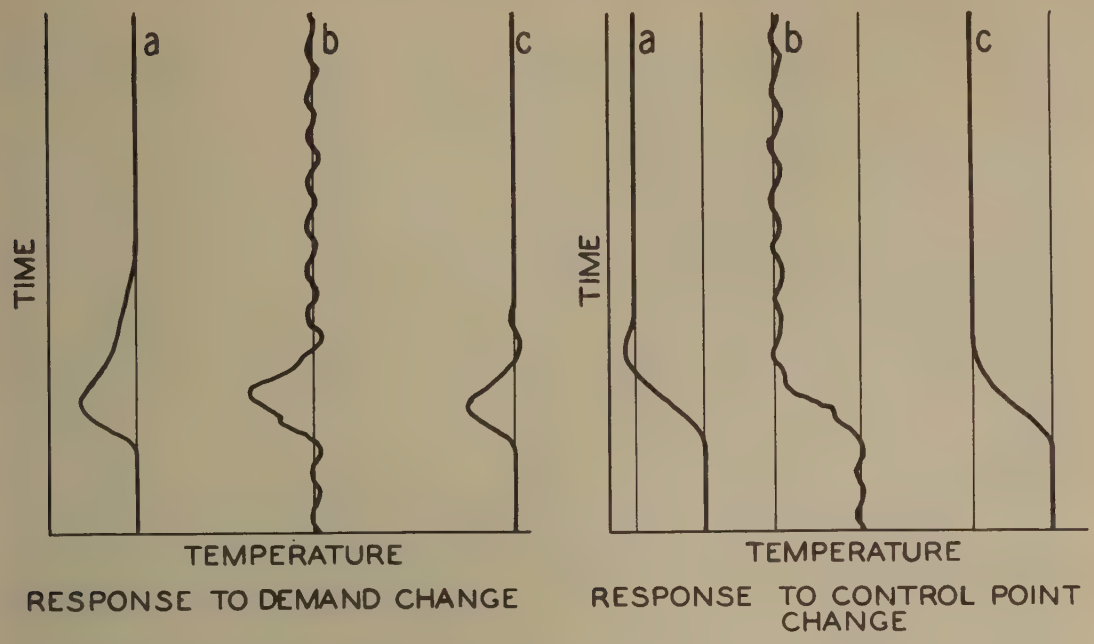


Fig. 10 — Effect of Reset Adjustment in proportional - plus - reset - plus - rate control:
Curves (a), reset too slow;
Curves (b), reset too fast;
Curves (c), reset correct.

The desirable setting is the maximum reset rate which the process will stand, so that the recorder pen may be returned to the control point as rapidly as possible after an upset. It should be noted however, that as the reset rate is increased, the basic stability of the control action is decreased. In general, the product of the RESET and RATE TIME settings should not exceed 1.0. Thus, if the RATE TIME setting is 2, the RESET setting probably should not appreciably exceed 0.5.

As the reset rate is increased, the control record must again be carefully observed. The appearance of a cycle which is considerably slower than that resulting from a too-narrow proportional band is a definite indication that the reset rate is excessive and should be reduced.

Figs. 9 and 10 illustrate the results of various settings in this stage of adjustment.

D. Introduce Approach Action

Introduce approach only after proportional band and reset adjustments have been completed. Approach should not be introduced at all if the process under control is continuous in nature. However, it will be necessary to use Approach action with batch-type operations to minimize process overshoot. The correct approach setting is made experimentally.

First observe the control performance with the approach dial turned to off. If there is overshoot of the control point, turn the approach dial to the right (closing the approach switch) and set the dial to its mid-position (50). Then observe the control performance on a process run. Increase the approach setting if overshoot is still more than can be tolerated. Take out some approach action by reducing the setting if the process response to a change of demand or set point is sluggish or slow. The optimum setting will be a compromise between speed of response and overshoot. Note that when approach is introduced there may be a slight amount of low-frequency cycling of the final control element. If so, decreasing the amount of approach action will not reduce this cycling. If the frequency of the cycling is too high, either turn off the approach action or reduce the reset action. The latter will reduce the cycling of final control element but will not eliminate it.

13. METER ADJUSTMENT

The output current meter has been factory calibrated and normally requires no adjustment in the field. However, should the meter be replaced, or its adjustment disturbed it can be recalibrated by means of the METER ADJ. potentiometer located on the rear of the front panel to the left of the meter. Connect a milliammeter of known accuracy directly in series with the panel meter (at one of the meter terminal posts) and adjust the potentiometer shaft to obtain equal readings on both meters.

14. REVERSE PANEL MARKINGS

Note that the CURRENT ADJUST dial is marked with an arrow to indicate the direction of increasing output current. In the usual electro-pneumatic installation, this arrow also indicates the "valve opens" direction of the dial. However, for installations where control action is reversed, the dial marking can be reversed by means of the appropriate foil label supplied with the control unit. If desired, the foil labels marked "open" and "closed" may also be applied to the panel to identify the open and closed ends of the output current meter.

The foil label is backed with a thin transparent sheet which must be removed before applications. To remove the backing, first place the label — back downward — on a wet cloth for two or three minutes. This will soften the backing sheet, which can then be stripped away from the label itself. Clean off any grease or dirt from the control unit panel, and apply the label to the panel, pressing or rolling the edges down firmly. The label will adhere tightly after 24 hours.

PART III

MAINTENANCE

15. PLUG-IN COMPONENTS

In the event of faulty control unit operation, the trouble can often be eliminated simply by substituting new plug-in units for those on the chassis. Specifically, electronic tubes and electrolytic capacitors are more often subject to failure than other components. Thus it is advisable to stock spare tubes and electrolytic plug-in capacitors as an aid to servicing the equipment (see recommended spare parts list, Section 16).

NOTE: If spare capacitors are kept on hand it is recommended that each spare be substituted for a capacitor in use at about 6-month intervals. The reason for this is that an electrolytic capacitor deteriorates if it remains unused for an extended period. Thus if two electrolytic capacitors are alternately used for about 6-month periods, a good spare will be available when wanted.

Other plug-in parts used in the control unit are the synchronous converter and the rectifier. Although these sealed units are considered to be more or less permanent components, they may be readily replaced, should this become necessary.

The Leeds & Northrup part numbers of all control unit components are given in Fig. 14. In addition, the number of each plug-in component is marked on the chassis, adjacent to the corresponding socket. When replacing such parts, always make sure they are properly seated and in the correct sockets.

16. RECOMMENDED SPARE PARTS

It is suggested that one of each of the following spare parts be carried on hand to facilitate control unit maintenance.

ITEM	L&N PART NO.
Converter (60 cycle units only)	354156
Converter (50 cycle units only)	354169
5879 tube	22-1-0-15
12AX7 tube	22-1-0-6
5963 tube	22-1-0-7
OA3 tube	22-4-0-2
Capacitor - 6 section	23-2-0-17
Capacitor - 4 section	23-2-0-18
Capacitor - 2 section	023121
Neon bulb NE51	026082

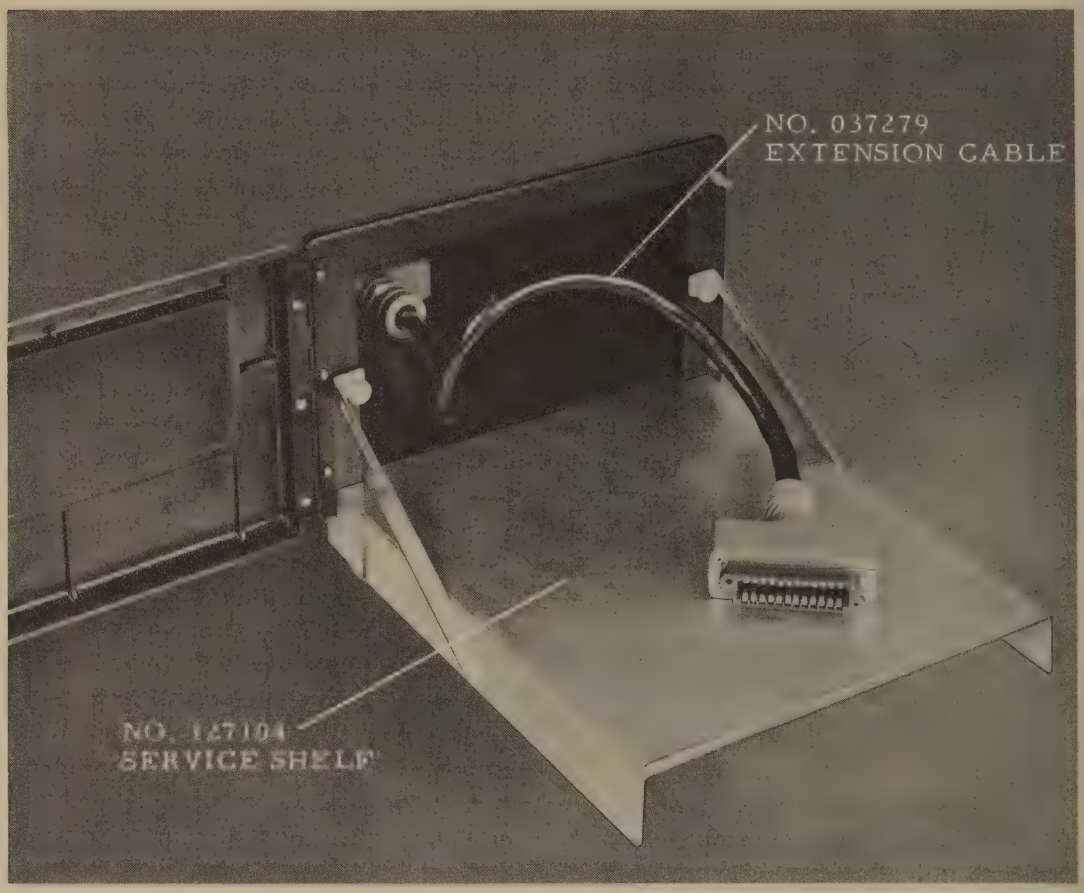


Fig. 11 — Panel mounted control unit case with shelf and cable attached for servicing.

17. TEST EQUIPMENT

The following items of test equipment should be available for making the tests described in subsequent sections:

(1) Volt-ohmmeter Analyzer

This unit is required for checking a-c and d-c voltage and resistance values. The analyzer should have 20,000 ohms per volt impedance on the d-c voltage ranges and 1000 ohms per volt impedance on the a-c ranges, since the voltages given in this booklet are obtained with a meter having these impedances. The Simpson Model 260 analyzer has the required characteristics. If a lower impedance voltmeter is used in measuring voltages across high resistance circuits, lower readings must be expected, and conversely.

(2) Special Test Equipment

The following equipment items, which may be purchased from Leeds & Northrup Company, have been designed to facilitate testing and servicing of Series 60 control systems.

(a) No. 127104 Service Shelf - This shelf attaches to the front of the control unit case, as illustrated in Fig. 11. It forms a convenient table on which to place the chassis for testing and servicing.

(b) No. 037279 Extension Cable - This extension cable is terminated with suitable plugs for connecting between the control unit chassis and case. It permits tests to be made while the control unit chassis is connected into the system as for normal operation. Fig. 11 shows the extension cable plugged into the case.

18. TROUBLE SHOOTING

A. Preliminary Tests

If spare plug-in parts are not available, or if replacement of such parts does not remedy the fault, proceed with trouble-shooting according to Table I. This table outlines the tests to be performed for various types of control failure. To use the table, select the applicable symptom under the "Abnormal Action" column. Then follow the test instructions in the order listed. Wherever an abnormal indication is obtained, make a separate check of the suspected components as indicated in the right-hand column.

B. Amplifier Test

If the tests of Table I indicate a faulty control unit amplifier, the amplifier can be tested as follows:

(a) Connect the chassis into the control unit case, using the 037279 extension cable. Normal connections to the control unit terminal board may be left intact. If a ground has been connected to the controller case, extend a connection from the case to the chassis.

(b) Turn AUTO-MAN switch to the dot position. Then apply a 1 mv d-c voltage between pins 2 and 4 of the converter socket. The 1 mv test voltage may be obtained from a portable potentiometer, or from a dry cell in conjunction with a suitable voltage divider network.

(c) Measure the amplifier a-c output between chassis and pin 6 of tube V2. This measurement should be made with a voltage calibrated oscilloscope if one is available. Peak-to-peak voltage will be 75 V if the amplifier gain is correct. If an oscilloscope is not available, a rough measurement of amplifier a-c output can be made with an a-c voltmeter. Output voltage should be approximately 30 V rms if amplifier gain is correct.

Low amplifier gain, indicated by a low amplifier output reading in (c) above, is probably caused by failure of the converter, tube V1 or V2, or

the 23-2-0-17 capacitor. If testing or replacing these parts does not locate the fault, check voltages and resistances at the V1 and V2 tube sockets. When an incorrect reading is obtained, test associated components until the faulty part is isolated.

C. Voltage And Resistance Measurements

All measurements are to be made under the conditions noted in Fig. 13. If dial settings and other conditions are not as specified, then some voltages and resistances can be expected to differ from the values given.

D. Replacing Components

When faulty parts are replaced, the new parts and wiring must conform to the original arrangement. When resoldering, use no more solder than necessary to produce a satisfactory connection.

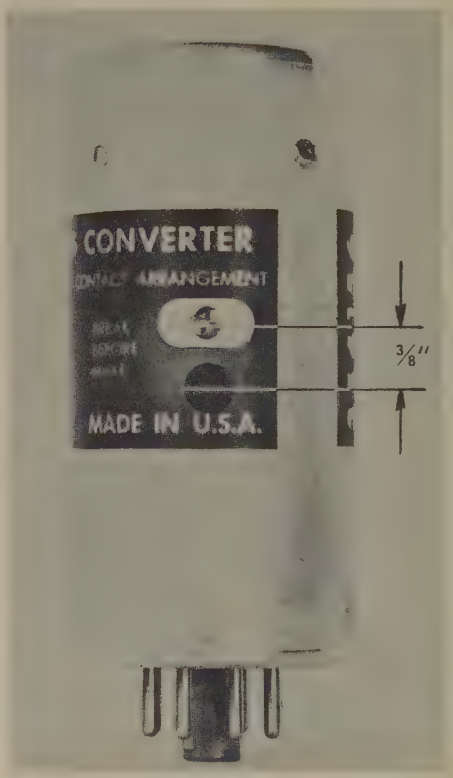


Fig. 12 — Location of converter adjustment hole. Other hole is diametrically opposite hole shown.

E. Check And Adjust Converter

To measure closure time of the converter contacts, first remove the converter from its socket but leave the top plug connected. Connect a volt-ohmmeter analyzer (ohms x 100 range) between pins 2 and 3 of converter base. With the converter held upright and the analyzer laid flat on a horizontal surface, note the analyzer reading on the 0-100 d-c volt scale. Connect the analyzer between pins 3 and 4 of the converter base and again note the reading. These readings are equal to the percentage closure times of contacts 3-2 and 3-4 respectively, and should be within the limits 35-45.

If converter closure times are not within the specified limits, the converter can be adjusted.

Use a sharp instrument to punch two holes in the metal label of the converter at the points indicated in Fig. 12. With the analyzer connected to measure contact closure, as described above, use a #6 hex socket set-screw wrench to turn the adjusting screws (accessible through the holes) until closure time is 40% for each set of contacts. The front adjustment (facing the viewer in Fig. 12) controls closure time between pins 2 and 3.

Turning the adjusting screw clockwise decreases closure time, and conversely.

IMPORTANT: After adjusting the converter, use a piece of nonmagnetic metallic tape to seal the holes in the case. This is essential since the entrance of even small amounts of dust may render the converter unusable.

F. Correct For Oscillation Difficulties

If the operation of the control unit indicates the presence of oscillation difficulties, correct for such difficulties by proceeding in accordance with the following general instructions:

(1) Examine all components of the control network for ground loops. If ground loops are found, eliminate them. If this does not correct for the oscillation difficulties, try removing the FC-65 ground link from the control unit.

(2) Extraneous a-c carried back through the control unit could cause an oscillation which might be picked up by the FH-FL leads of the control unit. Try to dampen the oscillation by connecting a capacitor or high value resistor across the FH-FL leads. Note that the proper value of the capacitor or resistor can only be determined by trial.

(3) Check the line supply to determine whether the oscillation difficulties are caused by the user's plant equipment. If they are, try to eliminate the cause of the difficulties.

G. Compensate For Calibration Offset Of Proportional Band Adjustment

The use of a 40% or a 100% control slidewire instead of the normal 20% control slidewire will cause a calibration offset of the proportional band adjustment. This shift in calibration may make it difficult to tune the proportional band adjustment to obtain proper control action.

The addition of a proper resistor to the feedback circuit will compensate for such a calibration offset. Adding the resistor reduces the feedback gain and compensates for the loss of error signal amplitude due to the increased slidewire length; therefore, the proportional band calibration is unchanged.

For a 40% control slidewire, connect a 2200-ohm, 1/2 watt, carbon resistor (part of 124398 Parts Kit) between terminals FC and FL of the control unit.

For a 100% control slidewire, connect a 560-ohm, 1/2 watt, carbon resistor (part of 124398 Parts Kit) between terminals FC and FL. It may also be necessary to add a resistance in series with the load to restrict the output current to 5 ma. The value of such a padding resistor is normally 1000 ohms. Removing the link between terminals FH and 66 will insert a 1000-ohm padding resistor that is already in the control unit. This modification will be required when the load exceeds 2000 ohms.

H. To Recalibrate The Approach Circuit

Calibration of the approach circuit is a factory adjustment. Recalibration is normally required only when the Zener diode Y2 or an associated component is replaced. If necessary to recalibrate this circuit, use the method given below, which requires no connections or disconnections to be made. It may be possible to perform this calibration while on control with little system upset if the process is fairly stable. The approach calibrate pot behind the panel is to be adjusted while the control unit is energized; therefore it will be desirable to use the extension cable, Part 037279, to operate the control with the chassis partially withdrawn.

(1) Switch to manual operation (MAN) until the dial settings are made, setting approach to maximum, proportional band to 10%, rate to off, and reset to any fast setting of about 100 repeats.

(2) Establish an error signal of about 5 volts. The most convenient way to do this is to turn off the recorder and manually turn the control slidewire until its contact is at the low end of its travel. This condition exists if the measuring pointer is below the set-point indicator by 10% of the scale for the ordinary 20% slidewire, by 20% for the 40% slidewire, and by 50% for the 100% slidewire.

(3) Switch to manual operation (MAN) and operate the drive mechanism to 99% open as indicated on the position meter.

(4) Switch to automatic and allow the output current to reach a maximum. Then adjust APPROACH CAL. as required to cause an output cycle of ±5% (or less) around 92% of maximum.

(5) To check the operation of the approach circuit, change the approach setting to 50 and turn off the reset. Move the measuring indicator toward the set-point index. The output should start to decrease when the indicator is about halfway between the low end of the proportional band and the set-point indicator.

TABLE I

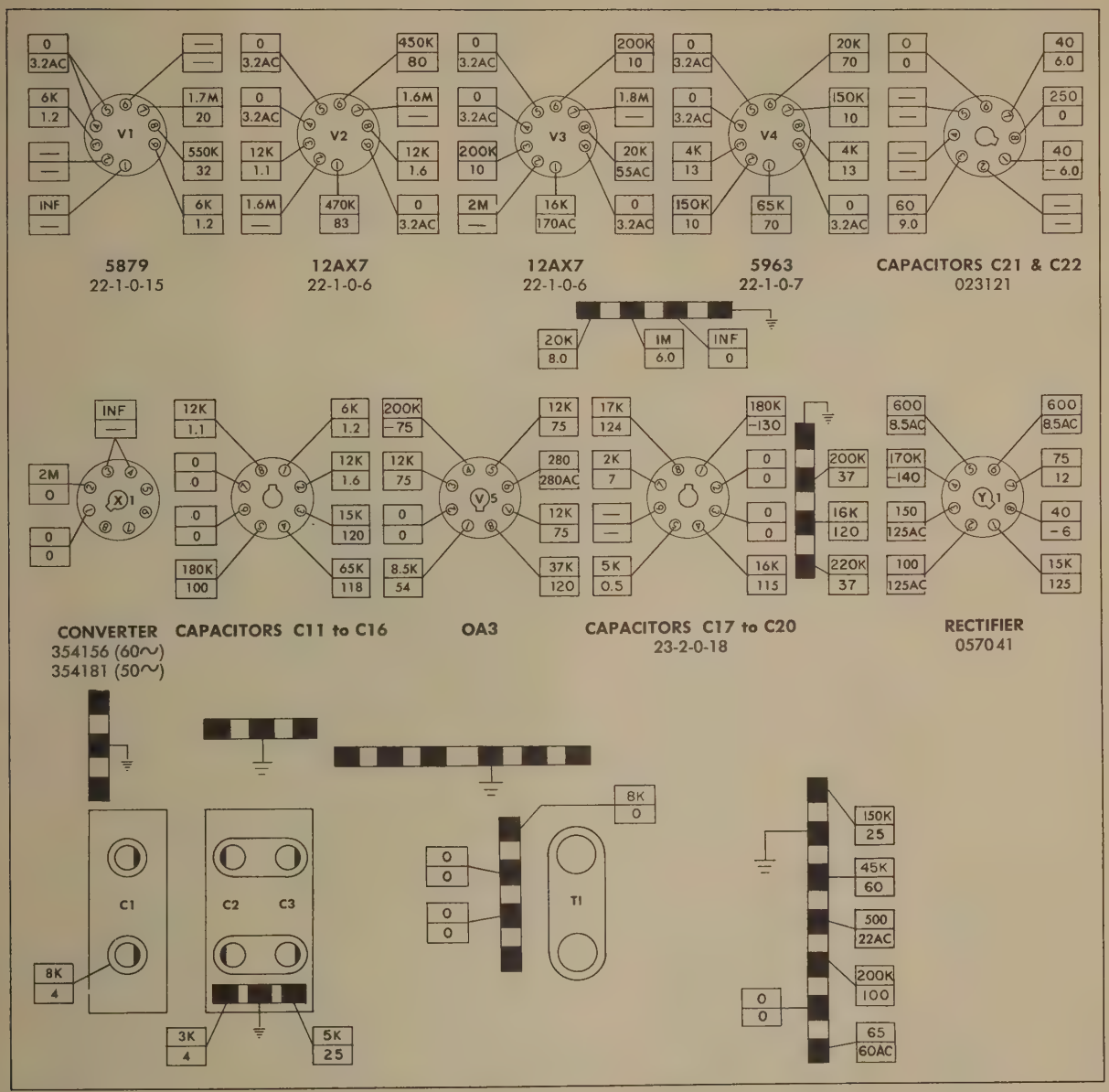
ABNORMAL ACTION	TEST INSTRUCTIONS	INDICATION		PROBABLE CAUSE OF ABNORMAL ACTION
		Normal	Abnormal	
Zero output current at all times	Set AUTO-MAN switch to MAN, CURRENT ADJUST to maximum. Observe amber light	On	Off	115v supply to controller not energized
	Measure B+ voltage between pins 4 and 3 of 23-2-0-18 plug-in capacitor socket	125v d-c ±10%	0	Shorted section in 23-2-0-17 or 23-2-0-18 capacitors. Faulty 057017 rectifier. Faulty power transformer.
	Measure resistance from 1A to FC with AUTO-MAN switch on AUTO	5000Ω ±20%	3000Ω Infinite	Load short-circuited Open connection to load
	Measure resistance across meter terminals as connected in circuit	200Ω ±20%	0	Meter adjusting pot (R7) shorted
	Measure resistance across meter when disconnected from circuit	800Ω ±20%	Infinite	Open meter coil
	Pass 1 milliamp. d-c through meter	5 ma ±10%	0	Faulty meter
Zero output current on MAN; low maximum current on AUTO	Observe VR tube (V5)	Lit	Out	Faulty rectifier V5 shorted, or R15 open C19 shorted R6 open
Zero output current on AUTO; normal output current on MAN	Set AUTO-MAN switch to AUTO; P.B. to 20; RESET to 100; set control point well above measuring pointer. Measure voltage across C4	+25v d-c or more	−12v d-c and below	Faulty 12AX7 tube (V3)
	Measure resistance from pins 3 to 15 of blue ribbon connector at rear of chassis	0	Infinite	High limit contact faulty or improperly set. Connections to high limit contact open. Faulty contact in blue ribbon connector.
	Short out C4 and observe output current	1.5 ma (approx.)	0	Faulty 5963 tube (V4)
Low output current on AUTO; no control action	Check resistance of C4 & C31	Infinite	0	C4 shorted C31 shorted
	Short out C10 and observe output current	4 ma or more	No change	V3 faulty

TABLE I (Continued)

ABNORMAL ACTION	TEST INSTRUCTIONS	INDICATION		PROBABLE CAUSE OF ABNORMAL ACTION
		Normal	Abnormal	
Low output current on AUTO; some response to changes in control point settings	Set AUTO-MAN switch to AUTO; P.B. to 20; RESET to 100; set control pointer well above measuring pointer. Measure B- voltage from pins 3 to 1 on 23-2-0-18	−130v d-c ±20%	0	Faulty rectifier R75 open C20 shorted
	Measure voltage across C4	+25v d-c or more	less than +25v d-c	R16 open Faulty 12AX7 tube (V3) R21 open R20 open R22 open C10 open R18 open
	Measure voltage at pin #6 of V4 to chassis	65v d-c ±20%	0	R35 open
	If above steps do not isolate trouble, the 5963 tube (V4) may be faulty and should be replaced.			
High output current on AUTO; no control action	Set AUTO-MAN switch to AUTO; P.B. to 20; RESET to 100; set control pointer well below measuring pointer. Measure voltage across C4	−12v d-c or below	+25v d-c or more	R17 open V3 faulty P5 faulty Amplifier out of order (See Section 18B.) R19 open
	If above steps do not isolate trouble, the 5963 tube (V4) may be faulty and should be replaced.			
No control response to set point changes; bumpless transfer from MAN to AUTO satisfactory; some reset action toward maximum output current at high reset settings.	Measure voltage between MC and MH	10-12v d-c	0	Faulty rectifier C21 or C22 shorted R27 or R28 open Faulty transformer
	Measure voltage across control slidewire	10-12v d-c	0	Faulty connections between controller and measuring slidewire
	Swing control pointer from 10% below to 10% above measuring pointer and measure voltage from MC to 63	−5v to +5v d-c	0	Faulty connection to control slidewire contact. Open circuit between terminals 63 and 64.
No control response to set point changes; bumpless transfer from MAN to AUTO satisfactory; considerable reset action in one direction or the other at high reset settings. Reset action independent of control point setting.	Measure voltage between MC and 63 while moving control pointer across the range.	Variable from −5 to +5v d-c	Constant ±5v d-c	Open connections between recorder and controller. Open control slidewire.

TABLE I (Concluded)

ABNORMAL ACTION	TEST INSTRUCTIONS	INDICATION		PROBABLE CAUSE OF ABNORMAL ACTION
		Normal	Abnormal	
Sharp change in current output as control pointer is moved past a particular point in respect to the measuring pointer, but otherwise no response. Bumpless transfer from MAN to AUTO is satisfactory.				Open control slidewire
Considerable change in current output when switching from MAN to AUTO	Set P.B. to 500%; RESET to 100; set control pointer above measuring pointer; AUTO-MAN switch to AUTO. Observe current output	Increases to 5 ma or more	Settles at less than 5 ma	C1 shorted
	Change RESET to .01; move control pointer below measuring pointer. Observe current output	Slight decrease	Goes to 0	C1 shorted
	Change P.B. to 100% and adjust control pointer for constant 2.5 ma output. Measure voltage from MC to 63.	±10 mv or less	more than ±10 mv	Faulty converter Faulty 5879 tube (V1) Poor amplifier gain (See Section 18B.) Excessive noise in measuring circuit.
No rate action				Shorted rate capacitor C3
Control point shift with changes in RESET adjustment.				Capacitor C2 faulty. Excessive noise in measuring circuit.
Control point shift with changes in P.B. setting and output current.				Faulty converter Faulty 5879 tube (V1) Poor amplifier gain (See Section 18B.)
Output current rises to maximum (5 ma or more) when controlled variable is below set point, and goes to zero when above for all P.B. and reset settings.				Damping capacitor (C2) shorted C7 shorted



NOTES

1—Lower section of each block gives voltage to chassis; upper section resistance to chassis. (Resistance measurements made with power off.)

2—Voltages are DC except as indicated. These are average values to be obtained with 115v AC line voltage.

3—Unit to be connected as for normal electropneumatic operation; i.e., terminals FC and 65 jumpered; jumper between FH and 66 removed; converter coil (or approximately 2000 ohm ½W resistor) connected between terminals FL and FH.

4—Control slidewire contact to be at center of slidewire (i.e., red and black pointers together).

5—Control settings to be as follows:

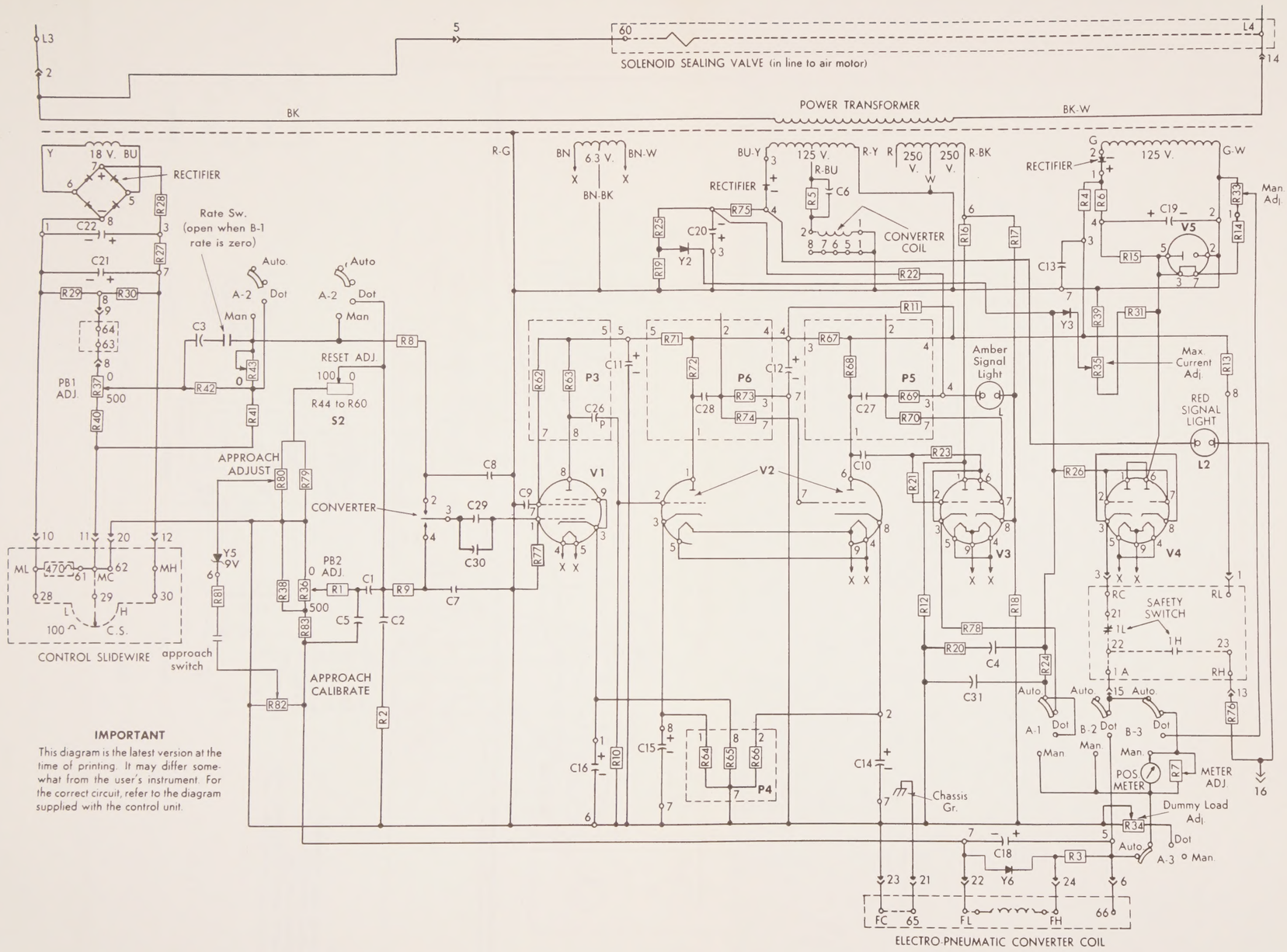
AUTO-MAN switch . . . . AUTO RATE 0
PROPORTIONAL BAND . . . 100% RESET 0

6—Current output to be adjusted as follows:

Turn AUTO-MAN switch to MAN and set CURRENT ADJUST dial to obtain 2½ ma. current output reading. Turn AUTO-MAN switch back to AUTO.

7—Abbreviations: M = megohms
K = thousand ohms
INF = infinite

Fig. 13 — Control Unit voltages and resistances.



IMPORTANT

This diagram is the latest version at the time of printing. It may differ somewhat from the user's instrument. For the correct circuit, refer to the diagram supplied with the control unit.

Fig. 14 — Elementary wiring diagram of 3-Action C. A. T. control unit chassis.

*RESISTORS

			Part No.
R1	6.8K		11-1-0-54
R2	2.7K		11-1-0-49
R3	1K		11-1-0-44
R4	1K		11-1-0-44
R5	2.7K	2W	11-3-0-49
R6	470Ω	1W	11-2-0-40
R7	1K		013278
R8	2.2M		11-1-0-84
R9	0.47M		11-1-0-76
R10	2.2M		11-1-0-84
R11	0.1M		11-1-0-68
R12	68K	1W	11-2-0-66
R13	22K	1W	11-2-0-60
R14	4.7K		11-1-0-52
R15	1.2K	5W	011525
R16	22K		11-1-0-60
R17	33K		11-2-0-62
R18	27K		11-1-0-61
R19	10K		11-1-0-56
R20	8.2K		11-1-0-55
R21	1M		11-1-0-80
R22	47K		11-1-0-64
R23	1M		11-1-0-80
R24	270K		11-1-0-73
R25	180K		11-1-0-71
R26	0.1M		11-1-0-68
R27	22Ω	2W	11-3-0-24
R28	22Ω	2W	11-3-0-24
R29	510Ω		11-11-0-6
R30	510Ω		
R31	22K		11-1-0-60
R32	18K		11-1-0-59
R33	10K		13-2-0-10
R34	10K		013308
R35	10K		
R36	10K		013140
R37	2K		
R38	2.7K		11-1-0-49
R39	10K		11-1-0-56
R40	270Ω		11-1-0-37
R41	1K		11-1-0-44
R42	10K		11-1-0-56
R43	2M		013141
R44	82M		11-1-0-103
R45	33M		11-1-0-98
R46	27M		11-1-0-96
R47	12M		11-1-0-92
R48	8.2M		11-1-0-91
R49	3.3M		11-1-0-86
R50	2.7M		11-1-0-85
R51	.2M		11-1-0-81
R52	.82M		11-1-0-79
R53	.33M		11-1-0-74
R54	0.27M		11-1-0-73
R55	0.12M		11-1-0-69
R56	82K		11-1-0-66
R57	33K		11-1-0-61
R58	27K		11-1-0-61
R59	12K		11-1-0-57
R60	82M		11-1-0-103
R75	2.7K		11-1-0-49
R76	.33M		11-1-0-68
R77	82M		11-1-0-103
R78	3.3K		11-1-0-50
R79	27K		11-1-0-61
R80	50K		013235
R81	10K		11-1-0-56
R82	200K		013281
R83	390		11-1-0-39

*All resistors are ½ watt with ± 10% tolerance except as specified.

†For chassis 354162 only. Converter for chassis 354181 is Part No. 354169.

CAPACITORS

			Part No.
C1	10µf	10vDC	023118
C2	24µf	5vDC	023119
C3	24µf	5vDC	
C4	5µf	200vDC	023383
C5	.5µf	200vDC	23-3-0-23
C6	.5µf	200vDC	23-3-0-23
C7	.05µf	400vDC	23-3-0-9
C8	.05µf	400vDC	23-3-0-9
C9	.1µf	400vDC	23-3-0-8
C10	.022µf	400vDC	23-3-0-20
C11	4µf	200vDC	23-2-0-17
C12	4µf	200vDC	
C13	4µf	200vDC	
C14	25µf	2vDC	
C15	25µf	2vDC	
C16	25µf	2vDC	
C17	50µf	3.5vDC	23-2-0-18
C18	12µf	210vDC	
C19	4µf	300vDC	
C20	4µf	300vDC	
C21	1000µf	12vDC	023121
C22	500µf	20vDC	
C29	.001µf		023125
C30	.001µf		
C31	5µf	200vDC	023383

PRINTED CIRCUITS

			Part No.
P3	R62	2.2M	144012
	R63	.47M	
	C26	.022µf	
P4	R64	15K	144011
	R65	6.8K	
	R66	15K	
P5	R67	.1M	144013
	R68	.47M	
	R69	1M	
	R70	1M	
	C27	.022µf	
P6	R71	.1M	144013
	R72	.47M	
	R73	1M	
	R74	1M	
	C28	.022µf	

MISCELLANEOUS

		Part No.
S1	Auto.-Man. Switch	031135
S2	Reset Switch	032292
L1	Amber Light	26-1-0-7
L2	Red Light	26-1-0-8
M1	Positive Ind. Meter	020006
V1	5879 Tube	22-1-0-15
V2	12AX7 Tube	22-1-0-6
V3	12AX7 Tube	22-1-0-6
V4	5963 Tube	22-1-0-7
V5	0A3 Tube	22-4-0-2
X1	Converter†	354156
Y1	Rectifier	057041
Y2 & Y3	Diodes	188059
Y5	Zener Diode	188115
Y6	Diode	057065
N1	Low Level Cable	037333
N2	High Level Cable	
N3	Converter Cable & Cap	037253
T1	Transformer	019184

COLOR CODE

BK	– Black	OR	– Orange
W	– White	Y	– Yellow
G	– Green	GY	– Gray
R	– Red	PU	– Purple
BU	– Blue	PK	– Pink
BN	– Brown	LBU	– Light Blue

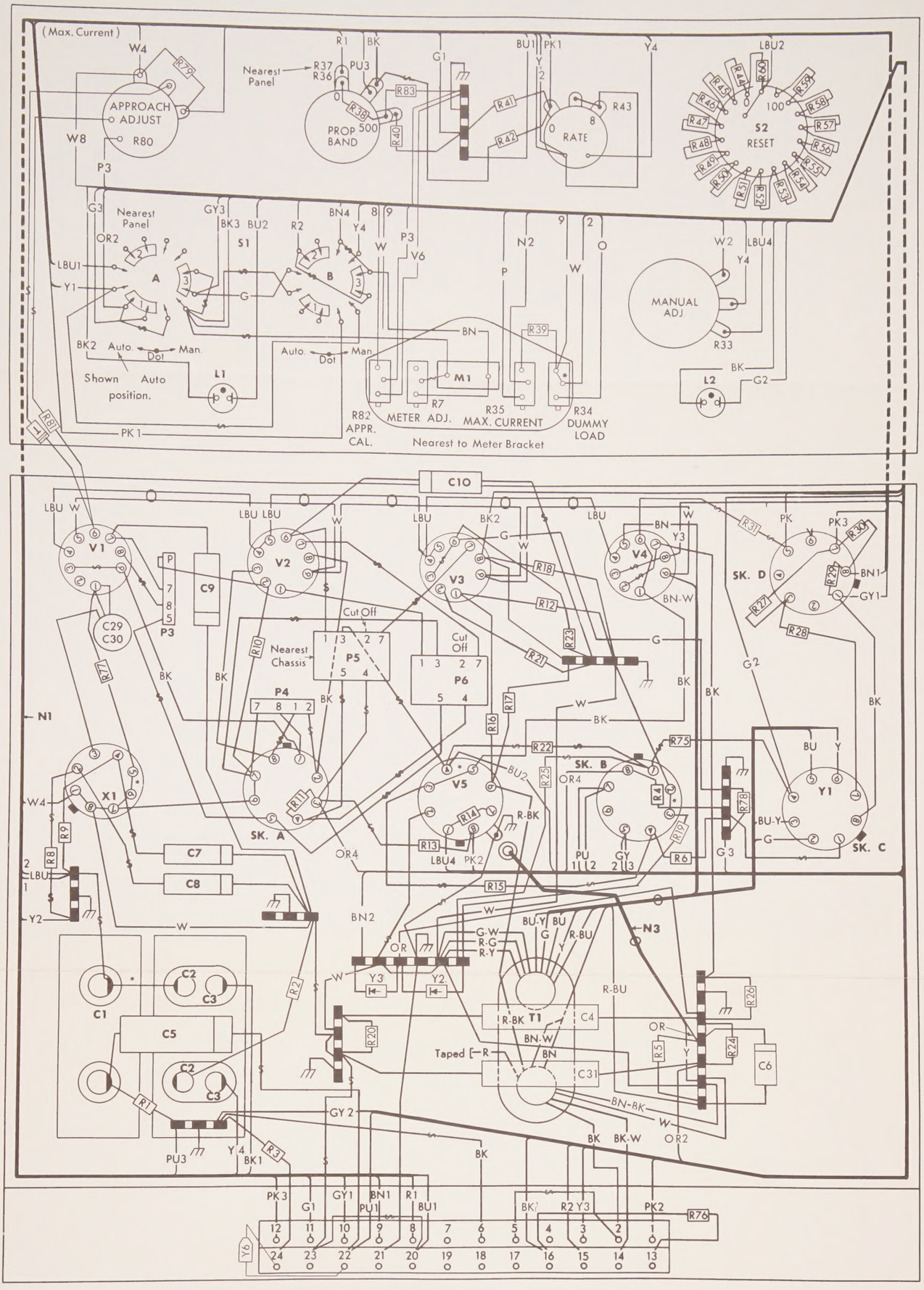


Fig. 15 — Actual wiring of 3-Action C. A. T. control unit chassis.

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